Assessment of human health risk for Lyme disease in a peri-urban park in southern Québec

Christina Tadiri*[1], Nick Ainsworth[1], Nathaniel de Bono[1], Sonia Gavin[1], Jun Li[1], Katherine Milbers[1], Lien Sardinas[1], Naomi Schwartz[1]

[1]McGill School of Environment, McGill University, 3534 University Street, Montreal, Quebec, Canada H3A 2A7

ABSTRACT

Introduction: Climate change has contributed to the spread of the hard tick *Ixodes scapularis* into increasingly northern latitudes, and subsequently has caused the spread of the Lyme disease causing bacterium, *Borrelia burdorferi,* into these northern areas. The spread of these ticks into the region of southern Québec is highly likely within the near future. As a result, new human populations are being exposed to these ticks and are at risk for contracting Lyme disease. **Intent**: This exploratory study examines the spatial and behavioral factors associated with human activity in Longueuil Regional Park in relation to risk for Lyme disease. **Methods**: We conducted exit surveys of park-goers to determine spatial and behavioral patterns of park use, as well as Lyme disease awareness. **Results and Conclusion**: We found higher awareness of ticks in female park-goers, park-goers over 50, and high-frequency park-goers. Our results, importantly, imply a discrepancy between peoples' awareness of tick bite precautions, and their perception of tick bite risk. We hope that these findings may help future research on the spread of Lyme disease into Canada, as well as in the formulation of public health policy.

KEYWORDS

Lyme disease, human risk assessment, climate change, public health

*Corresponding author:
christina.tadiri@mail.mcgill.ca

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INTRODUCTION

LYME DISEASE

Lyme disease (LD) is a multi-system pathology caused by the bacterium *Borrelia burgdorferi* in North America *(2)*. The hard tick species *Ixodes scapularis*, commonly known as the deer tick or black-legged tick, carries and transmits the disease. Primary and secondary hosts of the tick are the white-tailed mouse and the white-tailed deer *(3)*, while humans (and other mammals) act as inadvertent hosts. Bacterial transfer (i.e. through a tick bite) between vector and the human host can result in LD.

LD symptoms include fatigue, chills, fever, headache, muscle and joint pain, swollen lymph nodes, and a circular (bulls-eye) rash called *erythema migrans* which appears at the site of the bite *(4)*. If LD is left untreated, central and peripheral nervous system disorders, skin rashes, arthritis and arthritic symptoms, heart palpitations, and extreme fatigue *(5)* may develop, as well as recurring arthritis and neurological problems *(4)*.

Prevention of LD entails taking simple precautions such as applying insect repellent and minimizing skin exposure while outdoors so as to avoid bites from infected ticks *(6)*. Additionally, experts advise individuals to check their bodies and remove ticks before they attach to the skin, and to consult a physician upon finding any attached ticks *(7-9)*.

CLIMATE CHANGE AND THE SPREAD OF LYME DISEASE

Climate change, paired with anthropogenic land-use change, has led to an increased chance of tick survival and dispersion in southern Québec *(1)*. Until recently, winters in Québec had been harsh enough to combat the spread of ticks *(10)* since the ticks cannot survive winters, where temperatures regularly dip below –7°C*(11)*. However, increasingly warmer winters would lead to a higher survival rate for ticks, and consequently increase the chances of LD transmission. As human populations in North America grow, urban sprawl will likely perpetuate the trends of deforestation and forest fragmentation that will have lasting effects on the dispersion of rodent and deer species *(12)*. The effects of such fragmentation are particularly evident in a peri-urban park setting as Longueuil Regional Park.

Ogden et *al. (13)* created an algorithm based on passive surveillance data that combined vectors, climate change and host species data to determine the chances of the establishment of tick population in certain regions. They concluded that there is a high risk of such establishment in southern Québec and southern Ontario within the next ten years is high. This result implies that LD is a public health concern for Canada, as increased populations of ticks will pose a threat to a population that is perhaps currently unfamiliar with and unprepared for LD.

HUMAN RISK ASSESSMENTS FOR LYME DISEASE

There are currently a wide variety of approaches for conducting human risk assessments for LD. Several have focused solely on quantifying the risk of being bitten by a tick *(14-17)*. Other studies have incorporated a “transmission risk” element into their human risk assessments, where the bacterial seroprevalence in the tick population is also measured, combining the probability of being bitten by a tick with the probability that the tick is a carrier of *B. burgdorferi (18, 19)*. Others have considered risk on a broader scale, identifying environmental characteristics of areas (such as land cover type) that are associated with tick populations in order to create a risk index for an entire region *(20-22)*.

Despite these varied approaches, only a limited number of studies have taken into account both human behaviour and awareness in assessing the risk of LD contraction *(8, 9, 23)*. Recently, a study conducted in the Fôret de Sénart (France) attempted to integrate human and tick spatial distributions as well as human behaviour to develop a more comprehensive assessment of risk *(24)*. Our research has taken a similar approach to assessing risk by additionally evaluating human awareness and activity in a quantitative manner.

LONGUEUIL REGIONAL PARK

The study took place in Longueuil Regional Park (also known as Parc Michel Chartrand) located in Longueuil, Québec. An interview with park staff yielded the following background information: 1) the park encompasses 185 hectares and is bounded by several residential and commercial complexes; 2) due to urban expansion in the area, visitor numbers are increasing, with visitors participating in a wide variety of activities; and 3) within the park, there are several types of vegetation, a wide variety of birds and rodents, and a large population of deer estimated at around 50 individuals. The park’s peri-urban setting means that there is an increasing number of park visitors and close interaction with the wildlife; therefore, Longueuil Regional Park is an ideal study site for assessing the risk of contracting LD in a non-endemic area.

RESEARCH QUESTION & HYPOTHESIS

We gathered data with the intent of answering the following question: *What spatial and behavioural factors put the general public at risk for contracting Lyme disease in Longueuil Regional Park?* This project was designed as a descriptive research project. As such, we did not apply a specific hypothesis. The scope of this project was to assemble data in order to frame a picture of the larger relationship between human activity and tick density. This research question carries the implicit assumption that contact with infected ticks is necessary for contracting LD. To answer the above research question, we determined the factors that increase the risk of contracting the disease should the LD pathogen become prevalent in the Longueuil Regional Park tick population.

METHODS

We chose four of the most prominent park exits as points for survey sampling, then determined the number of surveys to administer at each exit based on the proportion of traffic at each exit. Researchers administered surveys verbally in French on one weekday and two weekend afternoons in early November.

The first part of the survey consisted of a user-friendly map of the park on which we asked respondents to trace the route that they traveled through the park on that specific visit. We then used Geographic Information Systems (GIS, ArcMap version 10) to analyse these data - we examined all traced maps, recorded the number of times each trail segment was used, and then layered this information into a GIS trail map. We also collected spatial data on projected tick distribution (based on land cover type) from a concurrent student-led literature review in the McGill School of Environment (unpublished report), and georeferenced those data into GIS, merging our spatial data with that of the students. Their literature review projected a high correlation between large oak tree areas and high tick densities *(3, 25, 26)*. We defined park areas of high population risk as sites with both frequent human visits and high projected tick densities. Therefore, the intersection of our trail buffer and oak tree areas is where humans were at higher individual risk for contact with ticks. The areas of highest population risk were defined as places where trail segments of high-frequency human visits intersected high tick density areas. To make the trails more visible as well as account for off-trail possibilities, a 10m buffer was applied around the trails.

The second part of the survey was a questionnaire designed to collect the respondent's demographics and behavioural information on that specific park visit. We specifically included questions pertaining to certain behaviours that have been identified in the supporting literature as conducive to tick bites, such as lying in the grass, going off-trail, or coming into contact with wildlife *(7-9)*. Questions regarding knowledge and employment of precautions against tick bites were also included. We organized and analyzed the data collected from the responses using Microsoft Excel 2007 and JMP 8 statistical software. We defined a working null hypothesis (H_0), which is that there was no significant difference in either reported behaviour or reported awareness of tick precautions between complimentary demographic categories (e.g. awareness likelihood of females versus males). We then performed $\chi 2$ analyses with an α-value of 0.05 to test H_1 for all relevant categories.

Finally, we merged data from questionnaires and trail maps using Microsoft Excel 2007, and performed a subgroup analysis of individuals who visited one or more high population risk zones; their behavioural and demographic characteristics were also compared to those of individuals who did not visit a high-risk zone to determine if any significant differences existed.

RESULTS

We identified several trails that represented the highest population risk zones in the park (Fig. 1): trails 3B, 5H, 5F, H5, H6, H7, and H8. We then removed the latter four for two reasons.

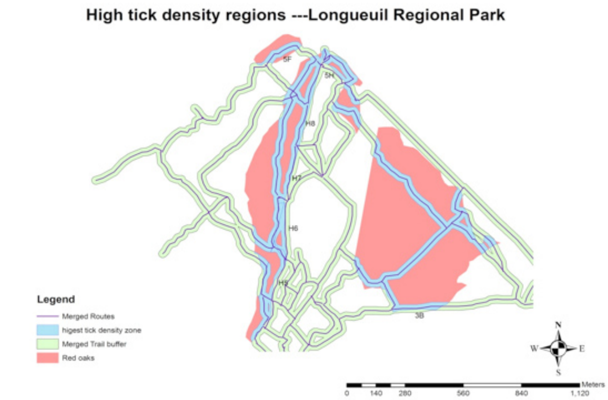

Fig 1. Overlay of high tick density vegetation onto trail map

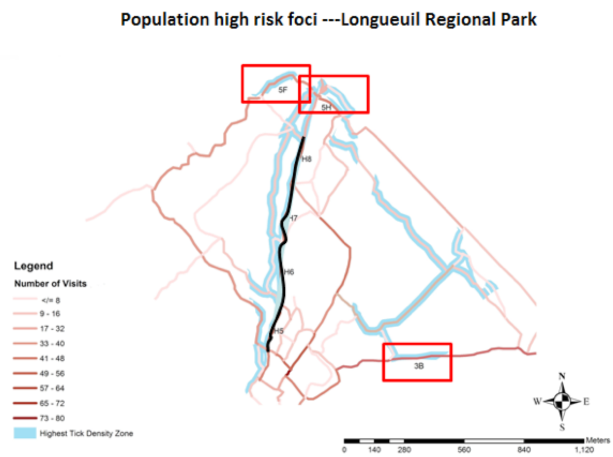

Fig 2. Isolation of high-risk foci. Segments H5, H6, H7 and H8 (black) were excluded from the analysisp

Comparison	Degrees of Freedom	p-value (α = 0.1)2	Direction of awareness
Gender and Tick Awareness (χ^2 contingency test)	1	0.0340	Females > Males
Age (<50 or ≥ 50) and Tick Awareness (χ^2 contingency test)	1	0.0420	50 and over > under 50
Exit Location and Tick Awareness ($\chi 2$ contingency test)	1	0.0660	Adoncour < all others
Frequency of Use and Tick Awareness (χ^2 contingency test)	3	0.0660	More frequent visitor > less frequent
Gender and Mean Age (independent samples T test)	101	0.1471	No relationship

Table 1. Summary of statistically significant results from park survey data

Firstly, these sections fall along the border of two different vegetation types: high tick density coverage (red oak) and low tick density coverage (grass, broad leaf trees, and marshland); this was not a clear indicator of risk. Secondly, these segments of path all belong to the wide *Coeur en mouvement* path, the only path in the park that is paved. Since the risk of contact with ticks on pavement is negligible *(27)*, we determined that this trail did not present significant risk to humans. The final map highlights the three "high-risk foci" that we defined (Fig. 2).

We collected questionnaires from 103 respondents. Within our sample, 45.6% of respondents reported awareness of tick precautions, but only 28.1% reported that they were actively employing any tick precautions on that day. 19.4% of respondents reported going off of the trails and 12.6% reported contact with wildlife. From χ^2 analyses of questionnaire responses, we identified four statistically significant relationships (α=0.1) (Table 1). While we originally set our α-value to 0.05, we have also included results in the $0.05 \leq \alpha \leq 0.1$ range since we feel that these relationships are important in their implications, while we recognize the greater probability of a Type-1 error. We found that females were generally more aware of tick precautions than males (p=0.034, df=1), and that respondents over 50 years of age were also generally more aware than other age groups (p=0.042, df=1). An independent samples t-test confirmed that mean age did not differ significantly between genders (p=0.1471, df=101), implying that these factors independently influence awareness. We also determined that respondents at the largest exit (rue Adoncour) were less likely to be aware of tick precautions (p=0.066, df=1) than those at other exits. Finally, we found a positive correlation between frequency of park use and precaution awareness (p=0.066, df=3).

We isolated three high-risk foci on our map: trail segments that received the highest human use and that were situated in a landcover type with highest projected tick densities. We identified 57 events where one of these segments was walked on, corresponding to 26 respondents. A comparison of demographical, behavioural, and awareness patterns of the 26 respondents with that of the population frequenting other areas yielded no statistically significant differences.

DISCUSSION

Some of the high-risk activities we identified were not significantly reported within our sample, possibly because of the weather and time of year. For example, only about 8% of respondents reported sitting or lying in grass. We feel that this activity requires further investigation since it is a significant risk factor for contracting LD; however, it may be much more common in the warmer months, also a time when tick populations are more abundant. About 20% of our sample reported going off-trail, indicating that it is fairly common and could be a potential source of population risk. However, we were not able to find a significant relationship between off-trail use and any specific demographic group, nor were we able to determine whether or not our subjects went off-trail in a high-risk area. Thus, based on our data, it is feasible to conclude that all users of the park are at roughly equal potential risk for tick contact and that no particular demographic group or activity is more likely to be associated with any particular area.

Given the relative ease with which LD can be prevented, knowledge of the disease and of precautions against tick bites is crucial in assessing disease risk at both the individual and population level. Since LD has only recently become a reportable disease in Canada (*5*) and the risk is relatively unknown or thought to be negligible, we expected very few of our subjects to be familiar with the disease and/or preventative measures against it. While LD is still fairly rare in southern Québec, our results show that a significant proportion of the population (nearly half) are aware of the disease and of preventative measures. However, we also observed a discrepancy between awareness of precautions and their actual employment of precautions. Less than two-thirds of those who reported being knowledgeable about preventative measures against LD reported taking any precautions; moreover, this value may be inflated due to cold weather encouraging the use of protective clothing. It is also possible that people misunderstood this question and listed the behaviours that they were aware of, even if they were not employing them. For these reasons, the gap between knowledge and behaviour is possibly larger than reported. This discrepancy is consistent with other studies performed in areas where LD is endemic *(23, 28)*. Some of the individual responses we received about employed precautions also indicated misinformation about the disease: this calls into question our reported awareness rate, and raises the possibility that awareness of actual tick precautions may be lower than the survey indicated.

Our results highlighted differences in awareness of tick bite precautions between different demographic groups. First, we found a significantly higher rate of awareness in females than in males, consistent with other reports of LD awareness in the United States *(23)*. Second, we detected an increase in awareness with age. Third, there was a marginally lower rate of awareness at the Adoncour exit (p=0.066, df=1), which is the most-used exit in the park. This difference was not likely a result of variations in frequency of use at the different exits, as frequency of use was not found to vary significantly by exit. This result, along with the demographic representativeness of users of the high-risk areas, reinforces that a general majority of park-goers are likely at risk for tick contact.

Contrary to previous studies in areas in where LD is endemic *(23, 28)*, we established a positive correlation between frequency of park use and awareness of tick precautions. The literature suggests that those knowledgeable about this disease tend to refrain from outdoor activities or avoid parks due to perceived risk of contraction *(23)*, which would negatively bias our awareness results. The positive correlation we identified could be explained by a low perception of risk for LD. It may be that subjects are (correctly) aware that the risk is currently negligible, and therefore use the park. Nonetheless, the low perception of LD risk coupled with the fact that ticks (albeit few) have been found in the park and that their numbers have been increasing in the area *(1)*, could constitute a key area for future public health interventions. If LD prevalence increases, public health measures will need to make the public aware of the actual risk--not simply precautions--in order to increase the employment of precautions.

CONCLUSION

With one exception, *(24)*, there are very few comprehensive assessments of LD risk based on human and tick distribution, as well as human behaviour and awareness. Our study is a preliminary attempt at addressing this deficiency in the literature. Since LD is relatively new to the area, now is the opportune time to be performing such risk assessments.

This project aimed to characterize the spatial patterns of future LD population risk and to elucidate some of the most pertinent factors that determine individual risk. We have also considered how these data might guide both policy planning and future research in a similar vein.

To better understand the human risk for LD in the future, it is important that future studies gather highly representative samples. The principal operational challenge for our research was the time of year at which it was conducted: we would strongly recommend that future work in this region be conducted during the summer months when response rates, activity breadth, and the feasibility of a larger sample size will all benefit from warmer temperatures.

Our results, while potentially significant, are preliminary. Thus, southern Québec in particular needs to be further studied before regional trends can begin to be extrapolated, and certainly before region- or province-wide public health action can be undertaken. We hope that future studies in this area can build upon these data, and also refine the methodology.

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